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THE SUITABILITY OF LAKES ON THE WINDMILL ISLANDS IN ANTARCTICA FOR PALAEOLIMNOLOGICAL STUDIES

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ABSTRACT

Forty three waterbodies were sampled in 1983 in the vicinity of Casey Station on the Windmill Islands. These included lakes on the Browning, Clark and Wilkes Peninsulas, and Herring, Holl and Warrington Islands, plus waterbodies adjacent to the old and new Casey Stations. Two samples of snow were also collected and analysed. A substantial data base was gathered with the following chemical and physical parameters obtained: major ions (Na, K, Mg, Ca, Cl, SO_4, HCO_3), minor elements (Sr, Li, Rb, Cs, Fe, Mn, Cu, Si, F, Br, PO_4, NO_3), plus dissolved oxygen, conductivity, water and air temperature.

Calculations of the mineral saturation indices for all the waters indicate that overall few of the waters are saturated with respect to carbonate minerals and silica. This indicates that there is a lack of biogenic skeletons/precipitates, and even if present at the sediment-water interface, they would probably dissolve rapidly within the sediment column through time. Accordingly, the undersaturation characteristics of the waters suggest that the lakes are unsuitable for palaeolimnological studies using diatoms or calcite/aragonite skeletons (e.g. gastropods, ostracods). On the other hand, the saturation of a few of the waters for magnetic minerals may perhaps lead to the search for suitable palaeomagnetic records if sufficient sediments are found at the bottom of lakes.

It was also found that at water salinities in the range of 120 to 1,500 mg/L a chemical precipitate concentrating Mg must form to explain the drop in the Mg/Ca of the waters compared to that of waters with different salinities. The identity of this precipitate is thought to be sepiolite as the lake waters prove to be commonly saturated with this mineral when mineral saturation indices are calculated.

The waters' molar Na+K / Mg+Ca ratio is characteristic of their locations on the Windmill Islands, with some waters from specific areas being obviously chemically distinct from those of others. The explanation for such chemical "provincialism" is clearly related to the particular geology of the various areas drained by the lakes. The local lithological control on water chemistry is also detected by comparing Mg with Si in the waters. Comments are also briefly made on the effect of penguin rookeries and human activity on the chemistry and other properties of the lakes in the area studied.

INTRODUCTION

Knowledge of the limnology of the waterbodies in the vicinity of Casey Station on the Windmill Islands in Antarctica was almost nonexistent until the sampling campaign described here was made in 1983 with the logistic support of the Australian Antarctic Division. Prior to that visit by P.D.D. information on the aquatic biota of meltwater pools in the vicinity of Wilkes Station on Clark Peninsula was published by Thomas (1965). In that paper, a brief list of the organisms found by Thomas was recorded in addition to some information on the salinity (range 0.8 to 24.3‰) of the 12 pools sampled. This paper led to the belief, prior to 1983, that there were several saline lakes near Wilkes Station, and this was one of the prime reasons for sampling the lakes on the Windmill Islands in the hope of finding saline lakes similar to those found in the Vestfold Hills near Davis Station, which have a good potential for being recorders of palaeoenvironmental change.

The other purpose for the visit to the Windmill Islands was to determine whether there was any relationship between the chemistry of the lake waters and the surrounding geology. The reason for undertaking such a project was that the chemical composition of the rocks in the vicinity of Casey, as described by Blight & Oliver (1977, 1982), spans a spectrum of lithologies from basic to acid. The advantage of being able to carry out this type of investigation in Antarctica is that there is no vegetation cover [although there is a sparse occurrence of lichens and mosses near the new Casey Station] which would otherwise affect some of the chemical processes normally occurring at the surface, and thus interfere with the chemical relationship that normally exists between that of the surrounding rocks and of the waterbodies.

WATER CHEMISTRY

Forty three waterbodies were sampled during the period of 4 to 19 January, 1983. Two samples of snow, with one fallen just before and the other during the sampling period, were also taken for analysis. The following parameters were measured on most of the samples:

-in the field: conductivity, water and air temperature, dissolved oxygen (using the standard Winkler titration method) and bicarbonate by titration in the laboratory soon after sample collection.

-in the laboratory in Canberra: major ions: Na, K, Mg, Ca, Cl, SO_4, HCO_3, and minor elements Sr, Li, Rb, Cs, Fe, Mn, Cu, Br, Si, F, PO_4, NO_3. It is important to note that analysis of the latter four elements was made on samples which were not specifically collected for that purpose and which had not been kept frozen prior to analysis.

Due to the space restriction given to the mansucripts for the present publication only selected and significant results on the water chemistry are presented here.

Complete analyses will be presented elsewhere (De Deckker, Kiss & Chivas, in prep.).

1. Salinity.

Overall the salinity of the waterbodies is very low, and this reflects the Antarctic conditions with most of the water directly originating from snow melt. Of the 43 samples, 13 have a total dissolved solids content (TDS) less than 100mg/L, another 15 have a TDS less than 1,000mg/L, 11 of the remaining have a TDS less than 3,000mg/L, and 2 lakes with a TDS in the vicinity of 4,000mg/L [on Herring Island and Clark Peninsula] and one with 8,105.5mg/L [on Herring Island]. Finally, a location on Clark Peninsula had a TDS of 31,538mg/L and this high salinity is explained by the fact that this pool is frequently in direct connection with the ocean.

2. The Na+K / Mg+Ca ratio

This particular ratio was calculated because of the significance it has for characterizing the different lithologies in the area. The study of Blight & Oliver (1977), which provides a substantial set of chemical analysis of the rocks, illustrates that typically the acid rocks [e.g. the charnockites on Browning Peninsula, the granite gneisses on Warrington Island and Clark Peninsula, and the leucogneisses on Bailey Peninsula near the old Casey Station] have proportionately high Na and K contents and low Mg and Ca. The basic lithologies [e.g. the basic gneisses on Herring Island and on Bailey Peninsula near the old Casey Station], on the other hand, possess low Na and K values and high Mg and Ca. The additional difference between the two principal rock types is that the former has proportionately a much higher percentage of SiO_2, commonly in the vicinity of 70%, compared to less than 50% for the basic gneisses.

The relationship of this ratio of monovalent cations over bivalent ones for the rock types is also recognised in several of the waters as documented in Figure 1. For example, it is evident that some "provincialism" is detectable for several of the areas. The waters on Warrington Island and Browning Peninsula are quite distinctive in comparison with those of Holl and Herring Islands. The waters near Wilkes Station, on the other hand, demonstrate the greatest regional variation, but this may be due to the fact that some of the waters may have been contaminated by some of the remaining building materials surrounding the Station.

3. The Mg/Ca ratio

The Mg/Ca of all the waters was calculated with the aim of detecting any possible

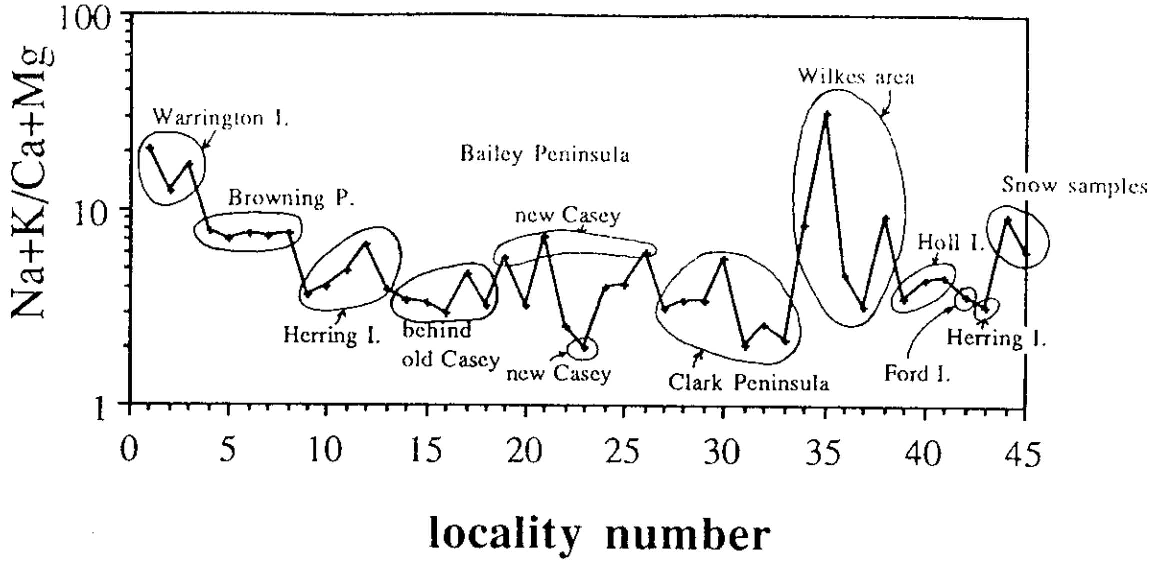

Figure 1. Plot of the molar Na+K / Mg + Ca ratio for all the waterbodies sampled on the Windmill Islands. Exact location of all the waterbodies will be provided elsewhere (De Deckker, Kiss & Chivas, in prep). Note the similarity of the ratio within specific regions (e.g. Browning Peninsula).

influence of sea spray on the water chemistry, especially for the lakes in the vicinity of the sea. First of all, it is interesting to note that once again the "provincialism" of some of the lake waters as recognised for the ratio of monovalent cations over bivalent ones is also found for some of the regions. For instance, Warrington Island and Browning Peninsula differ markedly from lakes on Herring Island and most of the other lakes in the area sampled. Several lakes possess a Mg/Ca in the vicinity of that of sea water (~5.2) and this phenomenon could be interpreted as being indicative of a marine aerosol influence. However, a plot of Mg/Ca versus TDS shows the following pattern: for waters with TDS below 120mg/L the Mg/Ca lies between 0.7 and 8; for TDS between 120 and 1500mg/L the Mg/Ca shows a narrow range of 1.4 to 1.8 except for 3 lakes on Holl Island which had a ratio of 5, 5.1 and 8.9; and for TDS ranging between ~1700 and 8100mg/L the Mg/Ca ratio ranges between 3.3 and 5.8. Note, in addition, that the Mg/Ca of the two snow samples fallen near the old Casey Station is 0.3 and 1.2. The ratio for these snow samples indicates that there is negligible marine aerosol component in the snow and that the latter's origin must be from inland.

The substantial change in the Mg/Ca registered between TDS values of 120 and 1500mg/L compared to the waters from below and above these TDS values indicate that a loss of Mg must occur at some stage during concentration processes.

Examination of the saturation indices (Log IAP/KT) calculated for the waters using the WATEQF program prepared by the US Geological Survey (Plummer et al., 1976) showed a number of the lake waters are either saturated or slightly undersaturated with respect to the mineral sepiolite [Mg_4 $(SiO_2)_3$ $(OH)_2$ $6H_2O$)] (Figure 2). The same applies also to some extent with other Mg-bearing minerals such as talc [Mg_3 Si_4O_{10} $(OH)_2$] and tremolite [Ca_2 Mg_5 $(Si_8O_{22})(OH)]_2$. Unfortunately no collection of lake sediment was made to verify if any Mg-bearing minerals do precipitate in the lakes. Note that an exception occurs for lakes on Warrington Island and Browning Peninsula which are undersaturated in Mg-bearing silicates and also have a low Mg/Ca ratio..

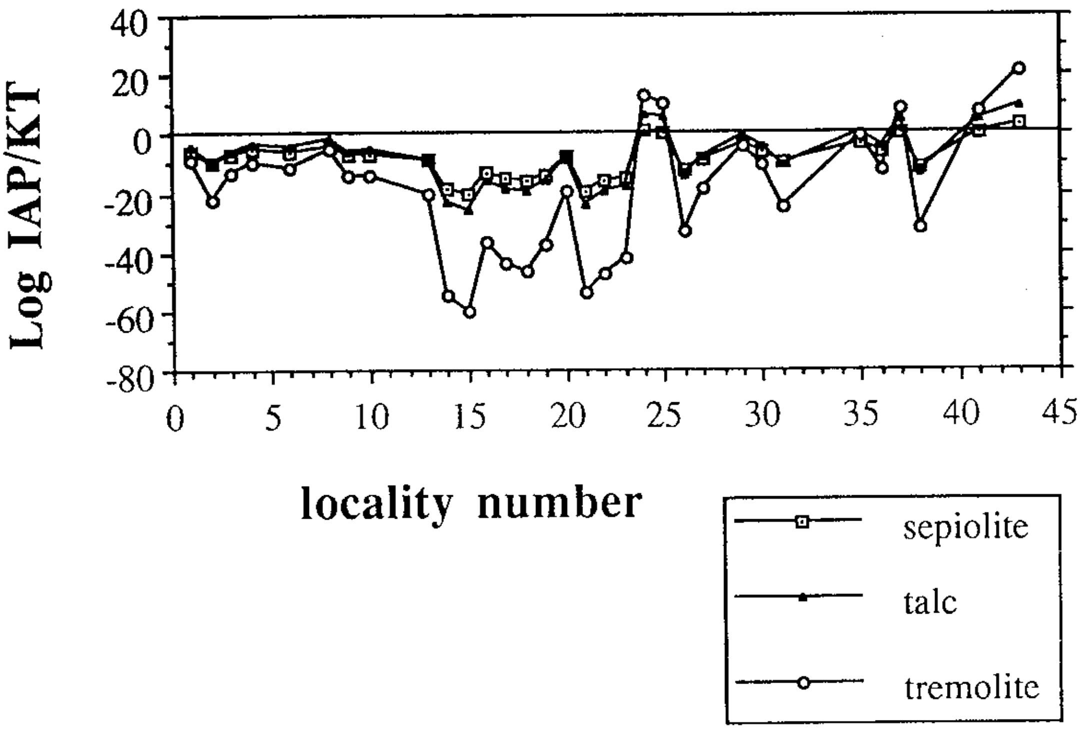

Figure 2. Plot of the saturation index (Log IAP/KT) of the various waterbodies from the Windmill Islands for sepiolite, talc and tremolite. Note that waters with saturation index (S.I.) >>1 are supersaturated with respect to the appropriate mineral, and those with a S.I. <0 are generally undersaturated. Calculation to determine whether a solution is in thermodymanic equilibrium with a particular mineral involves computation of the ionic activity product of all the elements involved in the formation of the mineral and knowledge of the ambient temperature, and thus the S.I.(Log IAP/KT) can be obtained by using the WATEQF program (Plummer et al., 1976).

4. The saturation of the waters with respect to calcite and quartz

Calculation of saturation indices of the waters for minerals which are important for forming and preservation of the skeletons of diatoms and other algae [e.g. quartz, chalcedony], and molluscs and ostracods [calcite and aragonite], indicates that several of the waters are undersaturated with respect to silica. Once again, the undersaturation of some of the waters in silica-minerals must relate to the surrounding lithology, as is clearly indicated for the Warrington and Herring Islands samples (see Figure 3, localities 1-3 for Warrington and 9,10 &13 for Herring).

The striking undersaturation of the waters with respect to calcite and aragonite explains the absence of organisms with a calcareous test during the 1983 sampling campaign and also that of Thomas (1965). Examination of Figure 4 shows that the only waterbodies which are saturated in calcite are two pools (localities 24 & 25) adjacent to Casey Station. The likely explanation for the saturation of the waters here are that these two pools must have been contaminated by cement dust during the building of the station. [It is also more than likely that a similar contamination must have occurred in the lakes near the new Casey Station built since 1983]. The other locations which are saturated are the pool in direct

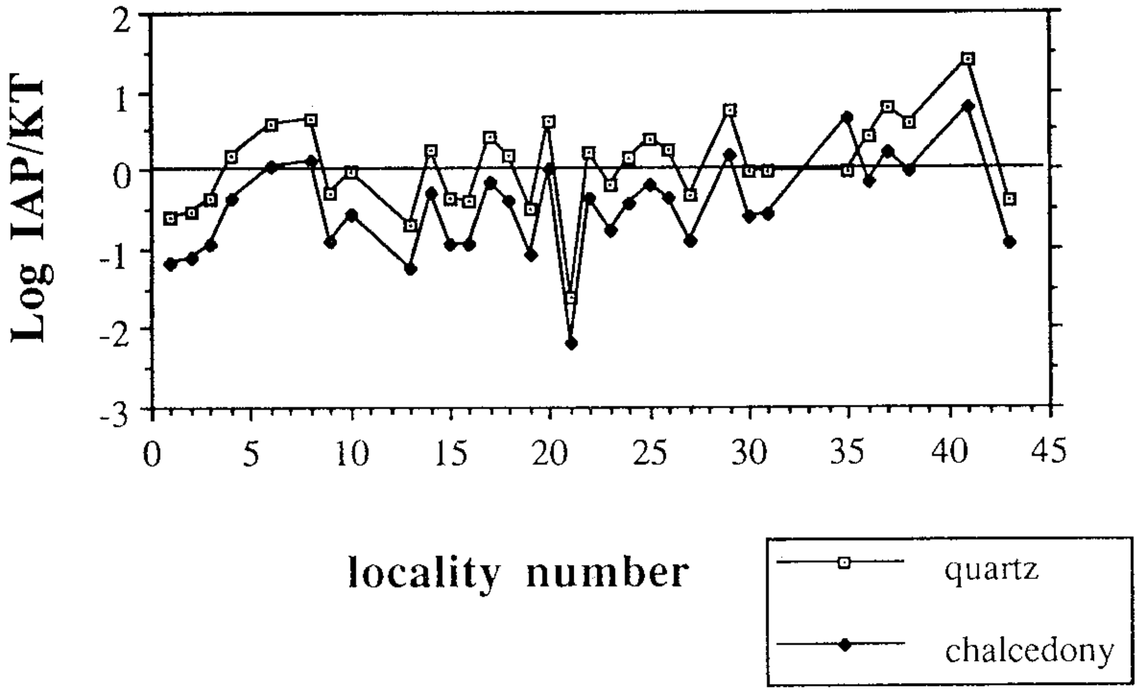

Figure 3. Plot of the saturation index (Log IAP/KT) of the various waterbodies from the Windmill Islands for quartz and chacedony using the WATEQF program (Plummer et al., 1976).

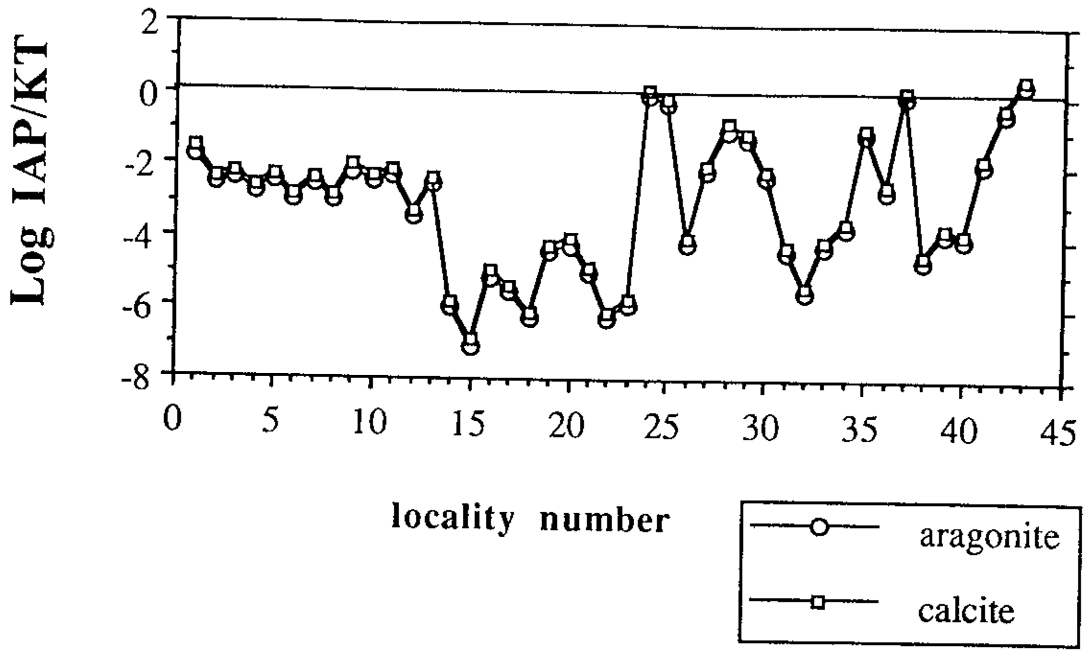

Figure 4. Plot of the saturation index (Log IAP/KT) of the various waterbodies from the Windmill Islands for calcite and aragonite using the WATEQF program (Plummer et al., 1976). Note also that the same waters which are saturated with respect to calcite are also saturated with respect to dolomite and magnesite.

connection with sea water on Clark Peninsula and the other one on Herring Island which has undergone a substantial amount of evaporation and thus has reached a salinity of 8‰. The same localities which are saturated with respect to calcite are also saturated to some extent with respect to dolomite and magnesite.

5. Fe-rich minerals

Although few of the lakes were sampled for Fe, calculation of the saturation indices (following the procedures used for the other minerals above) for hematite [Fe_2O_3], magnetite [Fe_3O_4] and goethite [FeO.OH] indicates that all sites for which analyses of Fe are available [localities 10-16 and 34, 35, 38, 40-41] have waters that are saturated to supersaturated with respect to all 3 minerals. Unfortunately, no collection of lake sediment was made at the time of water sampling.

DISCUSSION AND CONCLUSION

At first, it was quite a disappointment not to discover any very saline lakes in the area visited in 1983, and to acknowledge that the saline melt pools studied by Thomas (1965) where in fact in the proximity to the sea and thus in contact with sea water. In addition, it became apparent that many of the shallow lakes (<2m) on the Windmill Islands do not retain authigenic sediments on the lake floor due to the conditions in winter which cause the entire water column to freeze. Afterwards, ice must scrape the lake floor of any sediment in winter and also during the thawing processes. The only lakes with a potential to provide a palaeolimnological record are those which are quite deep, and more especially those that are adjacent to penguin rookeries. Such lakes receive a large amount of nutrients *via* the penguin guano, and thus algal productivity is enhanced due to the large amount of ammonia and other compounds draining into the lakes. Although water samples were not specifically collected for organic compounds, several analyses performed by E.K. in Canberra several months after collection demonstrate the enrichment of the waters below the rookeries compared to other waterbodies. In addition, due to the significant algal growth in the "rookery lakes", water quality assessment showed that turbidity was very high in such lakes, and also that temperature near the lake surface was definitely much higher than in the other, clear-water lakes as was the ambient air temperature. It is felt therefore that the deeper lakes [because ice scraping is likely to be less effective] and those near rookeries [due to the higher algal productivity] are likely to provide the best available sedimentary record for palaeolimnological studies.

It is also interesting to note that most of the lakes on the Windmill Islands have little potential for retrieval of siliceous or calcareous fossil remains for use in palaeolimnological studies. On the other hand, because of the apparent supersaturation of several of the waterbodies with respect to magnetic minerals (e.g. magnetite), it is likely that some of the deep lakes in the area, if they possess a good sedimentary record, would be suitable for palaeomagnetic studies. However, this cannot be assessed until lacustrine cores are taken.

Additional studies on the lakes situated adjacent to penguin rookeries may provide information on the lakes' present evolution as a result of eutrophication caused by the effect of penguin guano entering the lakes. Study of the sedimentary record of such lakes may also provide additional information on the evolution of such systems through time for annual to decadal and even millenarian time-frames. The palaeolimnological record of these lakes should also inform us of potential changes that are to occur in some of the lakes adjacent to the new Casey Station which are bound to be contaminated by human activity as was witnessed by one of us (P.D.D.) in 1983 when cement dust was blowing away from the building sites and fell into lakes..

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